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CLASSIFICATION

CANADIAN PATENT

LINER EXPANDER

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Granted to Pan American Petroleum Corporation, Tulsa, Oklahoma, U.S.A.

APPLICATION No. 897, 460

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PRIORITY DATE

No. OF CLAIMS

LINER EXPANDER

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This invention relates to a constant force spring device, and more particularly, to a device for expanding a metallic liner wherein an expanding die is urged against the liner by a constant force spring device.

Heretofore, a method and apparatus have been developed for installing an expanded metallic liner in an oil well or other conduit. Typically, a corrugated steel liner is inserted in a conduit which is to be lined, the greatest peripheral dimension of the liner being slightly less than the inside diameter of the conduit. An expanding tool is passed through the liner placed in the conduit, and a first-stage expanding die causes a gross plastic deformation of the liner, which is expanded outwardly against the inside of the conduit. A second-stage die on the tool then provides an additional finer deformation of the liner to provide a smoother, more finished surface on the inside of the liner and to assure more complete contact between the conduit and the liner. In a typical design of this type expanding tool, the frictional drag of the first-stage die supplies the expanding force for the second-stage die, which expanding force is a direct function of the strength, or wall thickness, of the conduit in which the liner is being installed. For example, in lining oil well casing, heavy wall casing may cause a very high frictional force which results in excessive pressure being required to push the expander through the liner. The application of the great forces required may result in rupture of the casing or in breaking the installing tool. In instances where the internal diameter of the conduit is somewhat less than that anticipated, the resulting forces can cause the tool to become stuck in the casing, or otherwise cause damage to the casing and the tool. In other designs, such as where a cantilever spring arrangement is employed in connection with the secondstage die, various difficulties are encountered in obtaining a spring mechanism having the desired strength in combination with the other spring characteristics, and with the tool dragging against the inside wall of the conduit after being passed through the liner.

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Since tools of the type mentioned above often are employed in wells deep in the ground, it is highly preferable that a tool be used which under no circumstances will become stuck in the well or cause damage to the well. Any such trouble occurring in a well can result in considerable loss in time and great expense in making repairs.

An object of the present invention is a device for applying a constant force to an expanding die or other similar apparatus so that a preselected maximum force is exerted against a work piece. Another object is an improved expanding tool for installing metallic liners in a conduit, which expanding tool can apply no greater than a predetermined force to the liner being installed in the conduit. Still another object of the invention is an economical and easily fabricated constant force spring device. A further object is a rugged, easy-to-operate expanding tool employing such a spring device. These and other objects of the invention will become apparent by reference to the following description of the invention.

In accordance with the present invention there is provided a constant force spring device which comprises a body member, an elongated column element adjacent said body member, bearing plate members contacting the two ends of said column at least one of said bearing plate members being longitudinally movable in respect of the other and stop means on said body member to limit the deflection of said column element to prevent permanent deformation of said column element upon the application of a compressive load thereto. In one embodiment of the invention, the foregoing constant force spring device is employed in a tool for expanding a metallic liner inside a conduit, said constant force spring device being positioned on said tool to urge an expanding die member against the liner being installed in the conduit by a substantially constant force.

My invention will be better understood by reference to the following description and the accompanying drawings wherein:

Figures 1A, 1B and 1C, taken together, constitute a partial sectional view of a preferred embodiment of a liner expanding tool according to the present invention; and

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                                       Figure 2 is a sectional view of the apparatus of Figure IA taken at
                             line 2-2; and
                                     Figure 3 is a typical plot of applied Load versus Deflection for
                           the constant force spring device of the invention.
                                   Referring to the drawings, Figure 1A is the bottom portion of a
                         liner expanding tool for use in installing a metallic liner in a well, while
                        Figure 1B illustrates the middle section of such a tool and Figure 1C repre-
                       sents the upper section of the tool. The expanding tool 11 is attached to
                      standard well tubing 12 by coupling 13 and, typically, may be lowered from the
                     surface through a well casing (not shown) to a point in the casing at which it
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                    is desired to install a metallic liner. Before inserting the tool into the
                   well, an elongated vertically corrugated liner 14 fabricated from mild steel,
                  or other suitable malleable material, is placed on the tool. The corrugated
                 liner is secured in position by contact at its upper end with a cylindrical
                shoulder member 16 and, at its lower end by contact with a first-stage expand-
               ing die 17 in the form of a truncated circular come which serves as a first-
              stage expanding die in the manner hereinafter described. The expanding die is
             fixedly attached to a centrally located, elongated cylindrical hollow shaft 18
            which forms a Portion of the body of the tool. As shown, the expanding die 17
           is held in place between a lower shoulder 19 and collar 21 threaded onto the
          shaft. A plurality of movable arms 22, preferably provided with outwardly
         enlarged portions 23 near the top, are disposed in the form of a cylinder
        around shaft 18. The enlarged portions of the arms 23 upon being moved out-
       vardly contact the liner to perform the final step of expanding the corrugated
      liner into a substantially cylindrical shape. The arm members 22 are pivotally
     attached to the shaft so as to be movable outwardly from the shaft by a tapered
    expanding member 24 slidably positioned on the shaft to serve as a second-stage
   expander. The surface of the member 24, as shown, moves upwardly along the
   shaft to engage with the arms and move them outwardly. Advantageously, the
 inside surfaces of the arms 22 and the outside surface of expanding member 24
form mating sections, typically octagonal in shape. The expansion of the arm
members is controlled by the position of the member 24 which moves upwardly
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until it contacts shoulder 26 provided on the shaft. As member 24 moves in a downwardly direction arms 22 fold inwardly toward the shaft. The expanding arms 22 are held in place on the shaft by collar 27 and circular groove 28 provided on the shaft.

The expanding tool, comprising the first-stage die and the secondstage die is drawn through the liner to expand it in place in the casing. The first-stage die provides a gross deformation of the liner so that it is expanded outwardly against the wall of the casing. The second-stage die then passes through the liner and performs the final expansion to smooth the inner surface of the liner and to provide more even contact between the liner and the wall of the casing and effect a fluid-tight seal.

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In operation, the liner setting tool is assembled at the surface, as described above, and a glass cloth saturated with a resinous material may be wrapped around the corrugated tube to form the liner. The assembly is lowered into the well at the location at which the liner is to be set. A liquid, such as oil, is then pumped under pressure down the well tubing and flows through the passageway 29 provided in polished rod 51, through ports 52 and into cylinder 35 connected to the upper end of the shoulder 16. Upon the application of fluid pressure to the cylinder, the piston 34 secured to polished rod 31 moves upwardly in cylinder 33. As shown, rod 36 connects polished rod 31 and shaft 18 upon which is mounted the first-stage expanding die 17. When the piston 34 moves upwardly through the cylinder 33 the expanding die 17 and the secondstage die 22 are drawn upwardly into the corrugated liner 14 and "iron out" the corrugations in the liner, so that the expanded liner may contact the inside wall of the casing in which it is being installed. Positioned on the shaft below the expanding member 24 is a constant force spring member 37 which is employed to urge the expanding member against the expanding arms 22 with a substantially constant force. The force exerted against the arm members being substantially constant, the force transmitted through the arm members to the liner and to the casing will be substantially constant so that either sticking of the tool in the casing or rupture of the casing is precluded. Of course, the force provided by the spring member is preselected so that the frictional

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forces between the tool and the liner and the pressure exerted against the casing are maintained at predetermined safe levels. The constant force spring member assures that the contact pressure between the liner forming portion 23 of the arms 22 is great enough to provide the desired deformation of the casing, while preventing damage to the casing or to the tool.

The constant force spring member 37 is slidably mounted on the shaft 18 and held between the expanding element 24 and a cylindrical lower shoulder member 38 forming a portion of a differential screw element 39 which transmits the loading on spring member 37 to shaft member 18. The differential screw element comprises shaft member 18 on the outside of which are cut male threads 18a, the lower shoulder member 38 provided with female threads 38a and thimble member 41 provided with threads 41a and 41b on the outside and the inside, respectively, to engage with threads on the shaft and the shoulder. The two sets of threads are coarse, such as square, modified square, or Acme threads, to withstand very high loads and differ in pitch so that shoulder 38 is moved upwardly on the shaft 18 when the shaft is revolved relative to thimble 41. The shoulder 38 is secured to the shaft 18 by splines 45 so that it can slide longitudinally, but it is not free to rotate on the shaft. Fixedly attached to the lower end of the thimble is a friction member, such as bow springs 42, a hydraulically actuated friction pad, or other such device for frictionally engaging with the inside wall of the conduit to secure the thimble against rotation with respect to the shaft. Preferably, the direction of the shoulder member threads 38a is the same as that of the shaft threads 18a, e.g. righthand threads, and the pitch, or lead, of threads 18a is slightly greater than that of threads 38a, with the pitch ratio being close to unity. In this manner, clock-wise revolution of the shaft relative to the thimble causes shoulder member 38 to advance upward slightly and a compression load is exerted upwardly on spring element 37 to cause buckling. For example, one satisfactory differential screw was made up using five and one-half threads/inch square threads on a shaft approximately 1.7-inch outside diameter and five and threequarters threads/inch square threads on a shoulder approximately 2.5-inches inside diameter.

Constant force spring element 37 comprises column element 43, advantageously consisting of a plurality of elongated columns disposed around shaft 18. Upper bearing plate member 44 is in contact with the upper ends of the columns and is slidably positioned on shaft 18 to transmit the force of the spring longitudinally against the bottom end of expander member 24. Lower bearing plate member 46 contacts the lower ends of the columns and is moved upwardly along the shaft by longitudinal movement of lower shoulder 38 as a result of revolving differential screw element 39. Grooves 47 are provided in each of the bearing plates, to form an upper race and a lower race, into which the ends of the columns are inserted. These grooves may be shaped to conform with the shape of the column ends if desired. A cover 48 may be employed to exclude foreign matter from the spring mechanism and to protect the spring.

A means for limiting the deflection of the columns is required. Although the column element functions in a buckled condition, application of excessive compressive load thereto would cause total failure or rupture of the columns. Therefore, a pair of stops 49 and 49a are provided for this purpose. As shown, the stops are rigidly connected to the bearing plates, and, in effect comprise upper and lower limiting sleeves positioned on the shaft to slide longitudinally thereon. The ends of the stops may move toward, or away from, each other as the load on the spring member varies. Lower sleeve 49a is prevented from moving down by lower shoulder 38 connected to the shaft 18. However, the spacing between the ends is such as to limit the longitudinal travel of the bearing plate members as they move together to prevent permanent deformation of the column element 43. Various alternative means for preventing damage to the column element may also be employed. For example, pins or rings mounted on the shaft may serve as stops, or the cover 48 provided with suitable connections may be employed for this purpose to limit longitudinal and/or lateral deflection of columns.

The columns of the column element 43 may be arranged around the shaft 18, which as shown here forms a portion of the body of the spring device, with ends of the columns fitted in the races 47. The columns may be

fitted closely together as shown, or may be spaced around the race, with separators used between them to maintain the desired spacing. The number of columns employed will depend upon column characteristics and the materials of construction. For exemple, the slenderness ratio of the column may be varied widely, and the column ends may be round, flat, fixed or hinged. The preferred construction is a thin, slender column with rounded ends, free to move within the races shaped to the curvature of the column ends. Materials which may be satisfactorily employed for the columns are carbon and low alloy steels, chromium and nickel-chromium stainless steels, various copper base alloys, such 10 as phosphor bronze, beryllium copper, the high nickel alloys and other similar materials providing satisfactory mechanical properties. Typically, the individual columns are of long rectangular cross-section, with the width being greater than the thickness, and arranged so that the wider face of the columns is normal to the diameter of the shaft. Thus, with sufficient compression loading, the columns buckle, and bend about the axis having the least moment of inertia, e.g., outwardly away from the shaft lo.

For example, a group of columns 0.167-inch thick by 0.438-inch wide by 10.626-inches long, with the ends rounded, were fabricated from A.I.S.I 4340 steel, quenched and drawn at 575°F. Each column was found to require a 20 critical compression loading of 450 pounds in order to buckle the column. After buckling, the columns were found to have a very flat spring characteristic, as shown in Figure 3, wherein P_c is the critical buckling load and point C represents the load and deflection at which the stress in the extreme fibers of the column exceed the yield point of the material. Theoretically, the shape of this spring characteristic curve is described by curve OA'ABC. Actually, this curve is described by OABC due to friction in the system. Points A and B represent typical working limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flexing cycles are not anticipated, a working stress just below the 30 yield point may be used, while with a great number of flexures, the working stress may be held to less than the endurance limit of the material of construction. In the above-mentioned tests, the lateral deflection was limited to

approximately one inch, at which the longitudinal deflection was approximately:
0.225 inches. From zero deflection to the maximum deflection, the 450-pound
loading was found to be substantially constant.

In another test a spring device was built, as shown, employing 20 columns, each having a critical buckling load of 1250 pounds. The lateral deflection was limited between 0 and about 1.00 inches by appropriately positioning the stops. Upon compressional loading, the spring element buckled at substantially 25,000 pounds and from a longitudinal deflection of 0.04 inches (buckling) to about 0.15 inches the load remained substantially at 25,000 pounds.

Of course, in designing a spring element as above it is advantageous to obtain the greatest possible value of longitudinal deflection for specified values of lateral deflection and critical buckling load, while maintaining the stress level in the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 1B and 2, with multiple flat members making up each column.

In the operation of the above expanding tool for setting a liner in well casing, the made-up tool is lowered into the well as mentioned above, with the arms 22 in the retracted position. When the tool is at the desired level, the well tubing is revolved. The friction member 42 engages with the wall of the casing and prevents thimble 41 from revolving. With several revolutions of the tubing, lower shoulder 38 is moved upwardly by differential screw 39 to buckle spring element 37 which has a predetermined critical buckling load. This load is transmitted upwardly against the lower end of expander 24, and its tapered surface is engaged with the tapered surface on the inside of the arms 22 to urge the arms outwardly with a substantially constant force proportional to the critical buckling load of the spring element. Subsequently, the expanding tool is passed through the liner to expand it in the casing in the manner described hereinbefore.

The foregoing description of a preferred embodiment of my invention has been given for the purpose of exemplification. It will be understood that various modifications in the details of construction will become apparent to

the artisan from the description, and, as such, these fall within the spirit and scope of my invention.

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- 1 1. A device for expanding a metallic liner inside a conduit which device comprises a shaft element, an expanding die member attached to said 2 shaft element, said die member comprising a movable liner-forming member 3 positioned on said shaft and being radially movable in respect thereof to contact said liner, an expander member slidably positioned on said shaft between said shaft and said die member to move said liner-forming member from said shaft, and a constant force spring member positioned on said shaft 8 to contact said expander member and to maintain said expander member against said liner-forming member, whereby said liner-forming member is urged against 9 said liner by a substantially constant force. 10
 - 2. In a device for installing an expanded metallic liner in a conduit wherein an expanding die is moved through a liner positioned in said conduit to expand said liner: a cylindrical shaft element, an expanding die member attached to said shaft, said die member comprising a plurality of arm members disposed around said shaft and being pivotable outwardly therefrom to contact said liner, a cone member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft, and a constant force spring member positioned on said shaft to contact said cone member and to maintain said cone member in contact with said arm members, whereby said arm members are urged outwardly by a substantially constant force.
 - 3. The device of Claim 2 wherein said constant force spring member comprises a plurality of columns disposed around said shaft, a first bearing plate member and a second bearing plate member, each of said bearing plate members contacting opposite ends of said columns, at least one of said bearing plate members being movably positioned on said shaft and being in contact with said come member, stop means connected to said shaft to limit the axial travel of said movable bearing plate member along said shaft, and compression means for maintaining a lateral deflection in said columns.

- 1 4. The device of Claim 3 wherein said compression means comprises
 2 a differential screw connecting said spring member and said shaft.
- 5. The device of Claim 3 wherein said stop means comprises a

 sleeve-like element connected to said movable bearing plate member and

 slidably positioned on said shaft and a member connected to said shaft to

 limit the travel of said sleeve-like element.
- 6. The device of Claim 3 wherein said columns have a rectangular cross-section, the width being greater than the thickness, and having the wider face normal to the diameter of said shaft.
 - 7. A device for installing an expanded metallic liner in a conduit which comprises a cylindrical shaft element; an expanding die member mounted on said shaft, said die member comprising a plurality of arm members disposed circumferentially around the outside of said shaft and being pivotable outwardly therefrom to contact the liner; a conical expanding member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft; a plurality of slender columns, each having a long rectangular cross-section and disposed circumferentially about said shaft; an upper bearing plate member and a lower bearing plate member, each slidably positioned on said shaft and contacting opposite ends of said columns; limiting sleeves attached to each of said bearing plate members and slidably positioned on said shaft; a shoulder member on said shaft; a differential screw element connecting said shoulder and said shaft to apply a buckling load to said columns; said shoulder being engageable with the limiting sleeve connected to said lower bearing plate member, whereby the axial travel of said bearing plate members is limited; said column members transmitting their buckling load to said arm members to urge said arm members outwardly with a substantially constant force.

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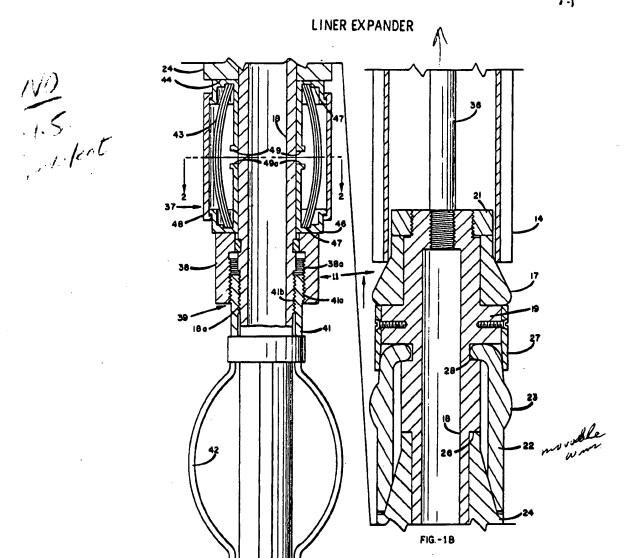
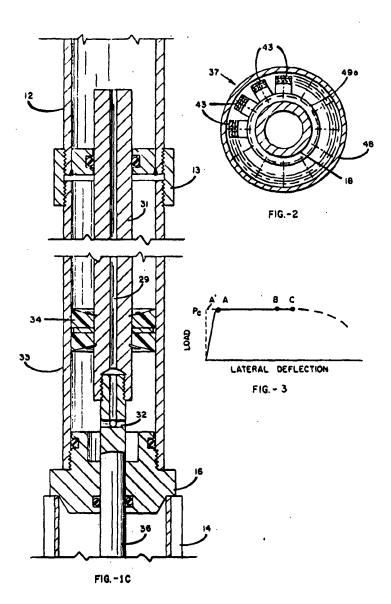


FIG.-1A



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Page 1 of 1



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I CLAIM

3. A device for expending a metallic line; touch a conclub which device somptions a shift almost, on arguming the member attituded to said and to closure, still die number comprising a movable liner-forming number positioned on said that and being catinly noroble in respect thereof to contact said liner, as expender nonber alidably positioned on said shaft between said shaft and said the number to move said liner-forming number from said shaft, and a constant force spring number positioned on said start to contact said argument system and to maintain shid argument sucher against said liner-forming number, admosts said liner-forming number, admosts said liner-forming number, admosts said liner-forming number, admosts said liner-forming number, as substantially constant forces.

2. In a device for installing an expended notallic liner in a

conduct wherein an expending the to wored through a liner positioned in sale

substate to exceed enth liners a cylindright start almost, an expending site

marker attached to said shaft, said the restor commissing a plausitly of any

substant stid liner, a come senter alightly positioned on said shaft between

the substant and said are numbers to targe said are members coincidely from said

shaft, and a constant force spring member positioned on said staft to conduct

stid one number and to extrate said one number in contact with said are

memory, phereby said my nothers are urged outwardly by a substantially

3. The ferior of Claim 2 shareds said constant force opting newer comprises a planelity of volume disposed around said sharts, a street bearing plate member and a second bearing plate scales, as leads of said bearing plate members occlerably opposite ofte of said columns, at leads one of said hearing plate members being movehly positioned on said starts and being in constant with said some number, stop means commerted to said starts to limit the axial traval of said movehle bearing plate member along said shart, and compression memor for unlateining a internal defloction in said columns.

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- A. The device of Claim 2 wherein each compression gonze comprises a differential sures consecute miss apring names and said shart.
- he retree stale prizant elderon him of Betramos in of their size of believes property that their an bestifies wideling
- 6. The device of their 3 wherein soid columns have a mestragalar obles, the width being greater than the Mildrows, and beaung the tides for several to the disaster of said shift.
- 7. A gavine for immilling on expended extellin liner to a combuit which comprises a syllustrical short almost, so expending the system countries on main shaft, said she sender compaining a plantity of are partners disposed restially around the outside of said shaft and being pivotable setthere orthogoly from said thatty a plurality of element columns, each baring a lang restingular opposes setting and disposed stransformatially whose said thatt; an upper bouring plate sender and a lower bearing plate scatter, such sitially positioned on said start and consecute apposite ands of said ner limiting alsows obtained to each of soid bearing plate numbers and alidably positioned on sold statts a shoulder number on much shafts a differential some places commetting will blooder and said short to apply a beginning load to outd enimmes said thousans being compatable with the 15. Miniting starts semmeted to estal lossy bearing plate mester, thereby the exist treval of mais bearing plate members is limited said column resident transmitting their buckling look to enid arm numbers to mrgs said and soul subspects with a substantially comptant force.

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Birmtufore, a cathod and apparetne have been developed for installing on expanded solution inner to us til mill or other compall, Typically, a correspond that liner is immerted in a conduct which is to be lived, the greatest perighant-disposion of the liner being slightly less the liner placed to the contact, and a first-stone especial att sense a gross plantic deformation of the liner, which is expended outworthy against the Inside of the combait. A stagend-stage die on the tool than provides an additional firms deformation of the limes to provide a smoother; re finished syrikes on the innie, of the line and to senge some somewhate one the contact and the liker. In a typical decigo of this type espending fool, the frietional drag of the first-stage die suggians the expending force for the second-stage die, which expending from in a kirect function of the strength, or wall thinkmou, of the conduit is which the limer is being installed. For example, in liming oil well cosing, beary will enting may sense a very high Existingal force which revelop in on m bidge pageired to push the expender through the liner. The prime at to radure at these was became everal force at to subjections or in breaking the impalling tool. In taskenes where the interest. nauth in monthag lass than they bed articipated, the resultge to the ensing and the tool. In other designs, much so that's a quatilever suring arrangement is ampliqued in accommittee with the sec stign die, verious difficulties are encountered in obtaining a spring tion beying the desired strength to continution with the other spring. characteristics, and with the tool dragging against the 19074s will of the module ofter bring passed blorough the limer.



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As shield of the present invention is a fevire for applying a conrient force to an expending die or other similar squeezies so that a preselected maximum frees to marted against a work piece. Another shipes is an improved expending tool for installing notable liners in a conduct, shich expending tool one qualy so greater then a predetermed force to the liner being installed in the conduct. Still amother object of the investion is an economical and entity februated expending tool coplaying reak a spring shipes in a regard, easy-to-operate expending tool coplaying reak a spring device. These and other chipsets of the investion will known apparent by reference to the failuring description of the investion.

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My invention will be better underwised by swinteness to the following description and the encountarying drawings wherein:

Figure 16, 18 and 16, taken together, countitute a partial sectional view of a pure repediment of a liner expending tool according to the present investion; and

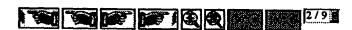




Figure 2 to a sectional view of the apparatus of Figure 1A taken at

Figure 5 is a typical plot of applied lock versus Deflection for the complete force spring device of the Levention.

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Suferring to the drawings, Figure 14 is the bottom portion of a timer expending tool for me in installing a motalile liner in a well, while a upper services of the tool. The expending tool il is ablanced to i wall toldag 15 by ampling 25 and, typically, may be lessyout from the surface through a well ensing (not shown) to a point in the swring at which it is desiral to invisit a metallic lime. Before inserting the test into the will, as alongsted vertically exemption timer in Cabricated Erro alid stool ing die 17 in the form of a tromested circular some which serves as a firstading die in the mount bereingfter described. The expending die is firedly abtended to a centrally located, elemented sylintrical bollow shaft lå is half in place between a lower shoulder 19 and coller 21 threaded eato the elect. A plurality of normalis arise 69, precessably provided with outserfly enterget portions 45 sear the top, wie disposed in the form of a cylinder around shaft 15. The unlarged portions of the term 25 eyes haing seved outnot the liner to portact the final step of expending the excreption .. ears where a we serve as stock out to describery videbile & rac STAIN to shape with the eras and more than outwardly. Advantageously, the es of the error 22 and the original engines of expension emelor 24 ting sections, typically categoral is shape. The expension of the arm re is controlled by the position of the member 24 reich moves appendly



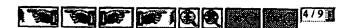
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mental it contents shoulder to provided on the right. As manher it women in a documently direction area for fall immunity toward the shorts. The expending axes 22 are held to place as the short by colley 27 and circular groove 20 provided on the short.

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In operation, the liner setting tool is used miliai et the serieco, so described shore, and a glass shoth saturated with a reviness material may be unapped stouch the corrugated tobe to flore the liner. The assembly is lovered into the wall at the lecation at which the liner is to be set. A liquid, such so oil, is thus pusped under processes does the wall tubing und flows through group to provided to polished rod 31, through ports 52 and into epitader 35 consected to the upper and or the shoulder 16. Upon the application of sure to the uplinder, the pistes 34 second to polished sut 51 name specially in criminar 33. As shown, not 36 comments polished not 31 and shaft 15 upon shigh is mounted the river-stage expending the 17. Then the piston A moves wearthy through the sylindar 33 the expending die 17 sed the secondstage die ER are trees speardly into the corrected liner in and "Iron pub" projections is the liner, so that the expected liner may content the rall of the centre in which it is being installed. Poritioned on the established through the are matern to the liner and to the casing will be substantially constant so that either shielding of the tool is the cestag or repture of the cardes is precluded. Of course,

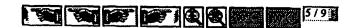


- 1 -



forces between the tool and the liner and the presence emerted agrices the oneing are maintained at predetermined safe levels. The constant force spring mather essures that the moviest presence between the liner forming portion 20 of the some 22 is great enough to provide the horized deformation of the sealess, while presenting demons to the challer or to the tool.

The constant force optics estate 37 is alidebly nouried on the short 36 and hald between the expending almost 26 and a splindrical lover chalder number 36 forming a portion of a disferential serve almost 39 which because the localing on opting number 37 to short number 16. The differential serve almost comprises short number 16 as the orderide of totals are only role threads 16s, the lover shoulder number 16 as the orderide of totals are only role threads 16s, the lover shoulder number 30 provided with forming threads 36s and thinkle marker 31 provided with threads his and hilly as the orderide and the instite, respectively, to suggest the threads and the shoulder and the shoulder. The two soles of threads are number, such as square, modified square, or done threads, to vitherand very high lands and differ in pitch so that monthly 30 is severed squarely on the short 18 when the short in revolved relative to thinkle \$1. The shoulder 30 is severed to the short \$1.00 epitches \$5 so that it can slide longithizably, but it is not true to revolve on the short. Finally stranded to the limits of the thinkle is a friction number, such as low springs \$2, a hydramically estated friction pat, or other west device for frictionally ampaging with the isolde mill of the tanget to occurs the thinkle square trustates with respect 50s to the short. Fracturally, the direction of the doubler number threads 30s, or it the girch rotte being above to make. It this is more to directly on operand 50s, or it the girch rotte being above to make. It thinkle summes thoulder number 35 to atvance square threads the constant larger threads on a spart approximately 1.7-inch outside dissectes and tive and threads dissecter.





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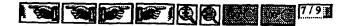
Constant force spring epament 37 comprises estimated by, accounts appeared a plurality of alongsted column disposed around shot's 18. Upper bearing place number is in a contact with the apper ands of the solumns and is although positioned on shart 18 to tresourt the force of the spring lengthelimally against the bottom and of expenden sember 28. Lower bearing place sember 66 contacts the lower made of the columns and 18 noved appearably along the shart by lengthesis never and of the columns and an account of the provided in seal of the bearing plates, to from an upper seas and a layer seas, into which the case of the column are inserted. These grooves my be shaped to contain with the shape of the column such if shaped. A cover is my be employed to amplied forwign matter from the spring mechanism such to protect the spring.

A name for limiting the deflection of the column to required.

Although the entum element furnitions in a builted contition, application of excellen acquirective load thereto would come total failure or repture of the column. Therefore, a pair of stope by each tips are provided for this purpose. As shown, the stope are rigidly connected by the bearing plairs, and, in effect comprise upper and lover limiting shares positioned to the shaft to alide longitudinally thereon. The code of the stope my store loverd, or say from, each other so the load in the opening number vertex. Lover places by its prevented from moting form by haver shoulder 55 nonnected to the shart 18. However, the spacing between the sade in much as to limit the longitudinal insual of the bearing plate mattern as they move together to prevent permitted furnished on the column alasmob by. Written alternative same for preventing damage to the column alasmob by. Written alternative same for preventing damage to the column alasmob by also be explayed, for example, plan or rings sometad on the chaft may serve as stope, or the cover 40 provides with estimatic councernous may be explayed for this purpose to limit inequinities and/or laternal declaration of columns.

The column of the column element by may be arranged around the thait 18, which as shown here forces a partion of the body of the spring deriver, with made of the columns fitted in the recess by. The solumns may be



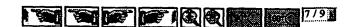


Fitted closely together as shown, or may be spaced around the race, with separations used botsoon them to extanted the desired spacing. The runker of columns employed will depart upon column thereselves and the emicrials of complementation. For example, the elementary robits of the column may be united widely, and the column ands may be would, flat, fixed or biaged. The preferred construction is a tide, element column with rounded made, from to now within the recent depart to the committee of the column ands. Materials which may be notificated and attainst when stainless the column and so allow situate, and through and minimal properties and minimal properties and minimal properties. Typically, the individual column are or long restamples cross-cention, with the wider stain bring prester than the thickness, and arranged so that the wider zoon of the notimal account of the attainst or the attainst. Thus, with marticiest compression louding, the orders backle, and here about the acts having the loast someth of inertial, e.g., puteratily may from the shart 15.

for example, a group of columns 0.16f-land thick by 0.535-inch wide by 10.656-inches long, with the ands younded, sears fabricated from 1.1.6.X 5360 steel, quescabed and draws at 577°F. Buth column was found to require a critical temperatura lording of 550 pounds in order to bookle the ealand.

After benkling, the columns were fromt to have a very flat spring characteristic, as shows in Figure 3, therein P₀ is the critical benkling load and point 0 represents the load and deflection at which the stress in the subject fibers of the selame exceed the pield point of the meterial. Theoretically, the chappe of this againg characteristic energy is described by some 06'ABO, Astanlly, this curve is described by 0AD due to friction in the system. Pytoke A and 3 represent typical vertical limits, which, at course, may be varied seconding to the application for sold the spring is designed. For example, where a large causes of flexing cycles are not soldelinated, a vertical attree just below the yield point may be used, while with a great number of flexing, the vertical attention stress may be held to been then the entermore that of the meterial of contring stress may be held to been then the entermore that of the meterial of contring

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systemize toly one inch, at which the longitudinal deflection was approximately 0.625 inches. From some deflection to the seminon deflection, the \$50-pound loading was found to be substantially constant.

In emother that a spring device was built, as sheen, employing 20 columns, each having a critical husbling load of 1250 years. The interal deflection size limited between 0 and about 1.60 inches by encryptately positioning the stope. Goes approximate locating, the spring element buckled of exhausticilly 25,000 pounds and from a long-toking deflection of 0.05 inches (making) to stook 0.15 knotes the load reactions substantially at 25,000 nounds.

Of course, in Conjuding a spring elected on above it in advantageous to obtain the greekest possible value of longitudinal deflection for specified values of loneral deflection and critical buckling load, while uninterlaing the strate level in the columns at a safe level. The preferred columns, therefore, are shown in Figures 13 and 2, with militale flat maternative, are shown in Figures 13 and 2, with militale flat maternative as each column.

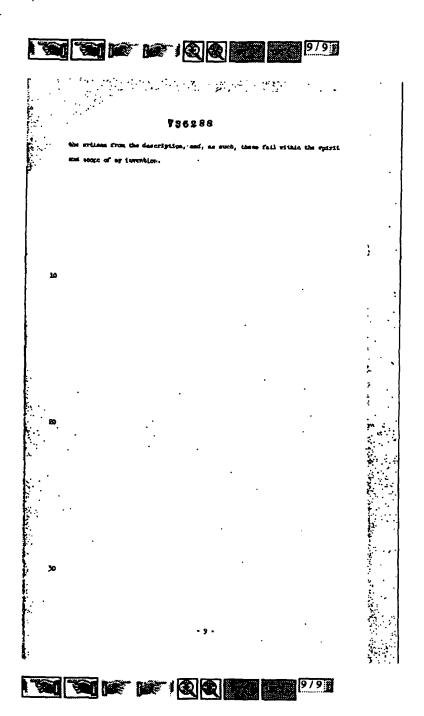
In the operation of the above expecting tool for writing a liner in well weing, the melo-up tool is lovered into the well as swettened above, with the area 22 in the represented position. When the tool is of the desired level, the well inhing is setoland. The frintion number it compare with the wall of the sening and prevents thinkle 4) from revolving. With several revolutions of the twing, know absolute 35 is novel assembly it differential server 39 to bushe againg alasmed 37 which has a predetention vertical buckling load. Whis long is transmitted aspectly against the lower and of expender 36, and its teperal markes is engaged with the tajectal surface on the initial of the error 22 to argu the tense contently vite a substantially constant force proportional to the critical buckling load of the spering almost. Subsequently, the expending tool is passed through the liner to expend it in the centing in the moner described beginsterne.

The foregoing description of a preferred embeliance of my investion.

has been given for the purpose of assemplification. It will be understood that
verious medifications in the defects of assertmention will become appearant to

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